UNIVERSITI PUTRA MALAYSIA

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THE PRODUCTION OF PALM KERNEL SHELL CHARCOAL BY THE CONTINUOUS KILN METHOD

By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science:

THE PRODUCTION OF PALM KERNEL SHELL CHARCOAL BY THE CONTINUOUS KILN METHOD

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The agro industry sector in Malaysia generates a significant amount of renewable biomass in the form of oil palm kernel residues. Palm kernel shells are one of the residues from oil palm industry and have long been used as fuel in boiler to produce steam and electricity for mill processes. These residues had disposal and environmental pollution problems. Carbonisation at present is a promising method to convert the palm kernel shells into charcoal. This study was carried out to determine the properties of palm kernel shell charcoal manufactured by the continuous kiln method. The carbonization of palm kernel shells was carried out in the 40 feet horizontal continuous kiln. The carbonization took placed at 400 ^{0}C, 500 ^{0}C and 600 ^{0}C, each for 30, 40, 50 and 60 minutes. The results show that the volatile matter 8.6% - 26.5%, low ash content 2.4% - 3.9% and high fixed carbon 70.7% - 88.2%. The bulk density of the charcoal is 661 – 781 kg/m^3. The palm kernel shell charcoal had reasonably high percentage of fixed carbon. The results indicate that palm kernel shell charcoal is suitable for industrial application such as a feedstock for the production of activated carbon.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations that have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institution.

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Date: 30 April 2001

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Malaysia stands proud as a country that brought oil palm from a minor crop to the status of a major commodity crop in world trade. Native to West and Central Africa, oil palm grows wild in groves with a few scattered tree per hectare. Commercial production of palm oil became important when the crop was introduced to the Far East by the way of the Botanical Gardens of Bogor in Indonesia and Singapore.

Oil palm is truly a golden crop of Malaysia – in terms of economic contributions from export earning for the country. Oil palm is grown for its oils. As vegetable oil seed crop, the oil palm is an efficient converter of solar energy into biomass. Besides being a prolific producer palm and kernel oil, it also generates a number of residues and by product. The residues of oil palm industry are from the field and mill.

The residues from the field include trunk and fronds at replanting and pruned fronds. The oil palm trunks are available only when the palms reach their economic life of about 25 years and are replanted. The fronds, on the other hand, are available at replanting and during the regular pruning and harvesting rounds.

The residues from the mill are produced during the milling of the fresh fruit bunches for the extraction of oil and kernel. The residues are mesocarp fibre and shell (Plate 1), palm effluent (POME), empty fruit bunch (EFB), boiler ash, bunch ash and palm kernel cake.

The expansion of the palm oil industry follow by the generation of enormous amounts of by-products at the plantation grounds, oil mills and refineries. In general the fresh fruit bunch contain about 27% palm oil, 6 - 7% palm kernel, 14 - 15% fibre, 6 - 7% shell and 23% empty fruit bunch material. It has been estimated that the milling processes produces about 7.6 million tonnes of palm mesocarp fibre, 3.1 million tonnes of palm kernel shell 12.4 million tonnes empty fruit bunches as residues annually (Chan, 2000).Palm kernel shell which pose a disposal problem are the potential feedstock for charcoal production.

1.2 Problem statement

Palm kernel shells are one of the wastes from palm oil industry, which have long been used as fuel in boiler to produce steam and electricity for mill processes. Palm kernel shell is the hard shell of the oil palm fruit seed that is broken to take out the kernel used for extracting palm oil. Thus, it is the by-products of palm oil processing during which the palm oil is extracted.

The palm oil mills generally have excess shells that are not used and have to be disposed off separately which otherwise would contribute to environmental pollution.

The conversion of the shells to charcoal is the good way to solve the disposal and pollution problem as well as to utilise the by-product.

1.3 Objectives

The choice of palm kernel shell in this study is not directed towards academic research only but also to diversify the source of charcoal. Palm kernel shells are abundantly found in this country as waste. The conversion of shell to charcoal might be a good way to solve the environment pollution problem as well as to use the by-products.

The objectives of this study are:

1. To obtain the optimum condition for carbonisation palm kernel shells.

2. To determine the effect of carbonisation temperature and residence time on properties of palm kernel shell charcoal.

3. To evaluate the feasibility of producing charcoal from palm kernel shells using commercial continuous kiln.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 The Oil Palm

The oil palm, *Elaeis guineensis* Jacquin, was first introduced into Malaysia in 1870, through the Botanic Gardens in Singapore. The oil palm industry was introduced to Malaysia in 1917 . The real impetus for the large scale planting of oil palm came about with the government's policy on crop diversification in 1960. As a result of the diversification and modernisation strategy implemented through the various agencies, the composition of crops has undergone a shift from rubber to oil palm. By 1970, the hectarage under oil palm increase to over a quarter million hectares reaching the 1 million mark ten years later in 1980. By early 1990s the area under oil palm in Malaysia exceeded 2 million hectares an expected to reach 3 million hectares by the end of this century . The growth of oil palm areas is shown in Table 1.

The increase in hectarage led to a corresponding increase number of oil palm mills and production of crude palm oil. The palm oil industry is primarily export-oriented.

Currently, there are 326 oil palm mills in Malaysia with a total production more than 8.32 million tonnes per years (Anon, 2000). In 1974 oil palm industry enter a new phase on its development with the establishment of the first palm oil refineries. Currently, there are 45 palm oil refineries in Malaysia with a total capacity of 12.73 million tonnes crude palm oil per years. Further downstream of the oil palm industry took place in 1982 when the first oleochemical plant was set up in this country and currently there are 13 oleochemical plants are in operation. Malaysia ranked as the world's largest producer an exporter of palm oil. (Yusof and Ariffin, 1996).

There is no denying that the industry has an impact on the environment. The oil palm industry as a whole generates a number of by-products and residues. It could be expected to occur both upstream in relation to the cultivation of the crops and also in the downstream processing activities.

The main residues from the milling of the fruit bunches are the mesocarp fibre, shell, palm kernel cake, boiler ash, empty fruit bunches, palm oil mill effluent (POME) and bunch ash. These by products are obtained at different stages of the milling process. The mesocarp fiber and shell are burnt as fuel in the boiler to produce steam and electricity for various mill processes.

Table 1: Area of oil palm plantation in Malaysia

Year	Hectares	% change
1871 - 1910s	<350	
1920	400	
1930	20 600	
1940	31 400	
1950	38 800	
1960	54 638	0.0
1970	261 199	169.4
1980	1 023 000	59.4
1990	2 029 464	36.9
1995	2 540 087	25.2
1996	2 692 286	6.0
1997	2 819 316	4.7
1998	3 078 116	9.2

Source: Statistics of Commodities, Ministry of Primary Industries

Based to the mature hectares in 1997 at 2,455 million hectares and in year 2000 at 2,813 million hectares, the amount of dry matter based on the fresh weight obtained by Chan *et al* (1981) for EFB, fibre, shell and POME are shown in Table 2.

Table 2: The amount of by-product from palm oil mills

Year	Location	By-products in million t/year			
		EFB	Fibre	Shell	POME
1997	Peninsular	7.823	4.797	1.947	23.806
	Sabah & Sarawak	3.028	1.856	0.754	9.213
		10.851	6.653	2.701	33.019
2000	Peninsular	8.288	5.081	2.062	25.219
	Sabah & Sarawak	4.146	2.542	1.032	12.616
		12.434	7.623	3.094	37.835

Source: Chan, 2000

The palm oil mill generally have excess fibre and shell which are not used and to be dispose of separately otherwise contribute to environmental pollution.. It is possible to derive good quality charcoal obtained from destructive distillation of palm kernel shells. The range products that can result from the destructive distillation of palm kernel shells is outline in Figure 1.

2.2 The Palm Kernel Shells

Palm kernel shells is the hard shell of the oil palm fruit seed which is broken to take out the kernel used for extracting palm oil. Plate 1 showed the cross section of oil palm fruit Plate 1. The proximate and ultimate analysis of palm kernel shells are given in Table 3.

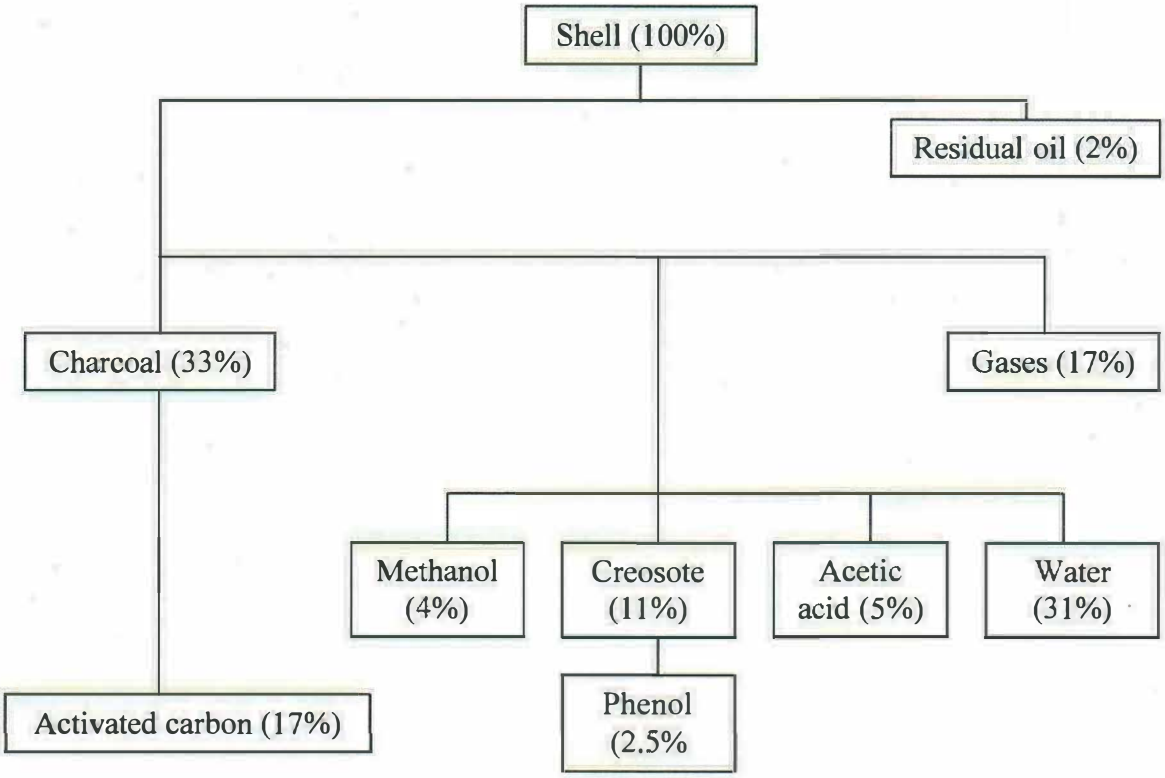

Figure 1: The destructive distillation of palm kernel shell (Chan, *et.al.*, 1976)

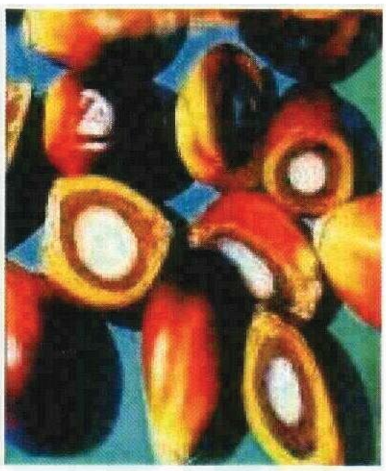

Plate 1: Diagram of cross section of oil palm fruit.

Table 3: Typical chemical analysis of palm kernel shell

Analysis	Palm Shell	Coal
Proximate analysis (%)		
Ash	2.50	4.48
Volatile matter	77.20	20.30
Fixed carbon	35.09	60.43
Ultimate analysis		
Carbon	55.35	83.75
Hydrogen	6.27	5.45
Oxygen	38.01	9.16
Nitrogen	0.37	1.64
Moisture content	8.40	5.73
Calorific value (MJ/kg)	19.56	30.42
Bulk density (k g/M^3)	440	780

Source: Farid and Gibbs (1994)

Due to its low ash content, adequate hardness and fairly high fixed carbon, palm kernel shell is generally to be a potential source for making quality grade charcoal (Plate 2).

Plate 2: Palm kernel shell

2.3 Charcoal

Charcoal is a very useful item but many people usually take it for granted. They know that it is used in barbecue cooking and other broiled food, but more often they do not realise that it has countless other uses, especially in industry. All species of wood can provide charcoal that suitable for general use such as fuel for homes and industry (Anon, 1957). Charcoal is also an important commodity for the reduction of steel, production of carbide and activated carbon in Malaysia.

The charcoal industry was introduced into Malaysia by charcoal burners who migrated from Thailand to Matang as a result of the exhaustion of the larger sizes of mangrove wood in their own swamps (Marshall, 1932; Robertson, 1940). The production and consumption of charcoal grew rapidly and showed a peak in the early 1950's, when charcoal was the preferred source of fuel for cooking (Anon, 1954). However, as a result of the energy revolution towards fossil fuels in the 1970's, the important of charcoal as a principal source of fuel for cooking decreased rapidly.

Charcoal is a carbonised amorphous material which is produced by carbonisation of organic material at 400 ^{0}C – 1000 ^{0}C. Charcoal is produced as a result of the chemical reduction of organic material under control conditions. The physical and chemical properties of charcoal depend very much upon the types of the raw material used and the conditions of the carbonisation process, such as temperature and method of carbonisation (Anon, 1956).

Carbonisation is the mechanism of pyrolysis process, i.e the heating of any particle of gaseous molecule in the absence of oxygen, and for solids it can be represented as the following equation:

$$C_aH_bO_c + \text{Heat} \longrightarrow H_20 + CO_2 + H_2 + CO + CH_4 + ... + \text{tar} + \text{char} \quad \text{(Tillman, 1991)}$$

Pyrolysis is the correct scientific term for the transformation which occurs in organic materials when it is converted by heat into charcoal and volatile materials of various kinds (Wenzl, 1970)

Bridgwater (1994) reported that the pyrolysis process produces charcoal, tar, combustible gases and number of chemicals mainly acetic acid and methanol and a large amount of water which is given off as vapour from the drying and pyrolytic decomposition of the organic material.

A generalised, solid fuel combustion model exists, built around the reaction sequence (Figure 2). The three classes of products of pyrolysis are volatile, tar and charcoal. The volatile were remain in the gas phase when at extreme high temperature. Secondary reactions involving the tar and volatile fraction produce compounds, which increase both the volatile and char yield from pyrolysis (Figure 3).

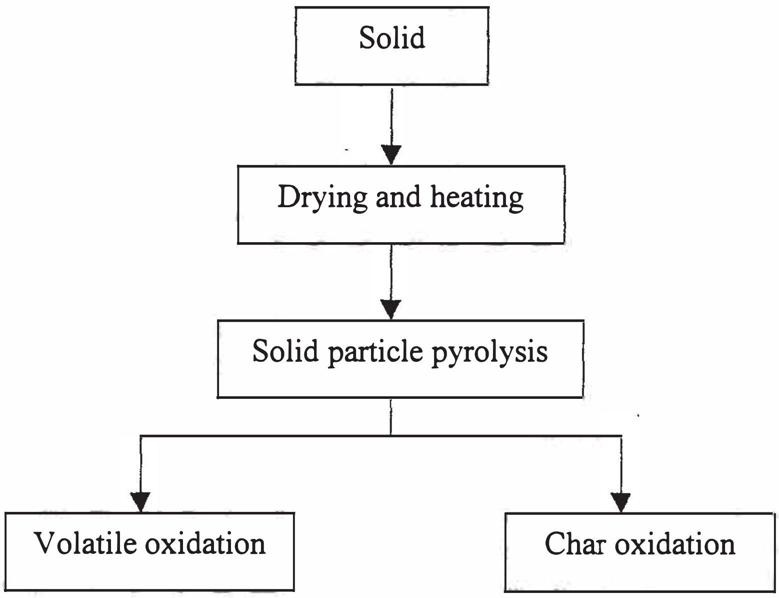

Figure 2: A simplified schematic of the sequential stages of solids combustion process

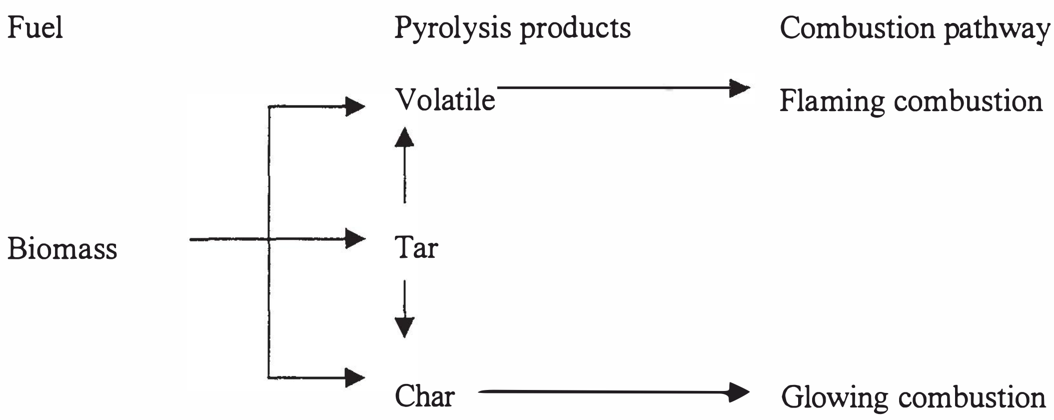

Figure 3: The global pyrolysis/combustion model (Shafizadeh, 1982)

2.4 The process of carbonization

When organic material in a kiln is heated up, it passes through a number of complex stages during the process of carbonisation. The carbonisation process can be conveniently separated into stages as follows:

2.4.1 Combustion (ambient to 600^{0}C)

The combustion process is necessary to ensure that enough dry kindling material is available to burn vigorously in the presence of ample oxygen so as to thoroughly heat up the charge before other stages can be sustained. The temperature rises rapidly during this period and, after an hour or when it reaches 600^{0}C, the air supply is reduced and the temperature allowed to drop to and the temperature allowed to drop to 100 - 150^{0}C. The organic material absorbs heat and is dried giving off its moisture as water vapor. The temperature of kiln remains at around 100^{0}C until the material is dried.